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# PRESERVATION OF PILING AGAINST MARINE WOOD BORERS.

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# CONTENTS.



# ILLUSTRATIONS.

# PRESERVATION OF PILING AGAINST MARINE WOOD BORERS.

## INTRODUCTION.

In many places along both the Atlantic and Pacific coasts the timber used for piles in wharfs and other marine structures is attacked by marine wood borers. The result is that the length of service of the piles is greatly shortened. Because the timbers best suited for piling are becoming very scarce and are increasing rapidly in price, some practical method of prolonging their life is needed.

The study of the character and extent of the damage done by marine wood borers and of the present methods of protecting piles against their attack, the results of which are contained in this circular, was made with the object of devising a method of protection which would be both efficient and cheap.

## WOODS USED FOR PILES.

To be useful for piling, a given timber must be tall, clear, and sound. It must be straight enough to keep the axis within the stick, and strong enough to support the necessary load, and should drive without breaking or splitting. Of the timbers which meet these demands, longleaf, shortleaf, and loblolly pine, white and red oak, Douglas fir, spruce, redwood, cedar, cypress, eucalyptus, and palmetto are the ones chiefly used. Of these, the first six have the widest use, the pines and oaks on the Atlantic coast and the Gulf of Mexico, and the fir on the Pacific coast. The others are used only locally.

## MARINE WOOD BORERS.

Almost invariably the marine wood borers are confined to salt water. In our waters there are two genera of mollusks, Xylotrya and Teredo, and three of crustaceans, Limnoria, Chelura, and Sphæroma, that seriously damage marine structures.

## XYLOTRYA AND TEREDO.[a]

Xylotrya and Teredo are popularly known as "shipworms." In structure and mode of life they are very much alike. Hence for all practical purposes a description of the work of Xylotrya will be sufficient. (See fig. 1.) When very young Xylotrya attacks the exposed surface of the wood in countless thousands and immediately begins to bore. The hole by which it enters is minute, but beneath the surface the burrow is soon enlarged to accommodate the rapidly growing body. The burrows extend usually in a longitudinal direction and follow a very irregular, tangled course.

There is some controversy as to the method by which boring is accomplished. It is possible that the body is held rigidly by an extensile suckerlike foot, ordinarily incased within the two shell valves (fig. 1, *a*), and that the two valves revolve around this, cutting the wood away with fine, hard, toothlike protuberances. It is possible on the other hand that the muscular ring near the posterior end of

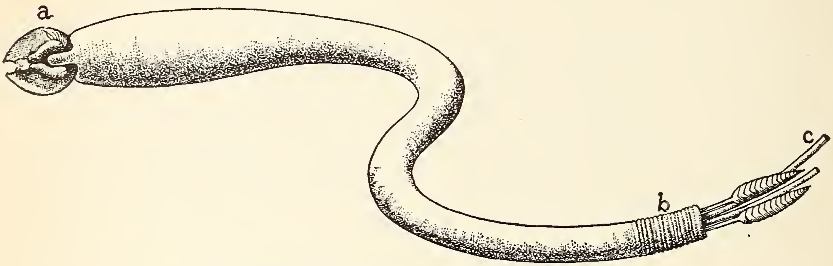


FIG. 1.—Xylotrya. (Description of a, b, and c given in text.)

the body (fig. 1, *b*) is pressed firmly against the walls of the burrow, and that the whole body, including the shell valves and foot, revolves slightly in both directions, the shell valves doing the cutting. It is probable, however, that the boring is done by a united action of the valves and foot. The posterior muscular end is probably the only portion of the body held rigid. The valves revolve slightly, cutting into the wood, partially in front and partially on the sides. At the same time the foot, either by the secretion of an acid substance, or of spicules used as a grinding medium, assists in breaking down the wood fibers directly in front of the advancing mollusk. The hardest knots are penetrated with ease, but the softer parts of the wood are preferred. As the body grows it secretes a calcareous substance to

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[a] There seems to be much confusion in the identification of these two borers. During the present study Teredo was found in a single locality, while Xylotrya, popularly supposed to be the Teredo, was very abundant along the Atlantic and Gulf coasts. In many places shipworms on exhibition labeled Teredo proved on examination to be Xylotrya. Literature on the subject is meager. Dr. Paul Bartsch, of the Smithsonian Institution, is at present revising and reclassifying the known species in order to assist in their identification.

form a hard lining around the burrow. This is thicker in soft, porous woods than in those which are hard and dense.

At the posterior end of the body, just below the muscular ring, are two siphons, or tubes (fig. 1, *c*). Through the shorter one the fine wood borings are ejected with the excreta; through the longer one water and food are taken in. The food consists wholly of infusoria, and is not obtained from the wood itself. The sole object of boring into the wood is to secure a place of shelter.

Xylotrya rapidly attains maturity. High temperatures promote quick work and hasten bodily development. The size attained by the adult depends upon the species, the locality, and the obstacles to excavation. In rare cases a length of 6 feet, with a diameter of over 1 inch, is said to be attained. Other species seldom attain a length of over 5 inches or a diameter of over one-fourth inch.

The portion of the pile commonly attacked is that between mean tide-water mark and a point about 4 feet below low water, though sometimes it extends downward as far as the pressure of the water will permit. The entrance holes do not indicate the extent of attack, as the entrance may be at mean tide-water mark and the active boring head several feet above. On the other hand, part of the excavation may be below the mud line, though the entrance is never so situated. More than one-half the weight of the structure may be removed without any visible signs of deterioration upon the surface. When the worm is dead, the minute entrance holes often become filled with mud or other débris, so that it is impossible to discover the true condition of the pile without chopping into it.

Undoubtedly all shipworms thrive best under the influence of heat, though some can endure a relatively low temperature. Certain species have been reported from as far north as Eastport, Me. Since warm water increases their activity and permits them to continue their attacks throughout the greater portion of the year, shipworms are most destructive from Chesapeake Bay south to Florida, on the Gulf of Mexico, and along the entire Pacific coast.

The shipworm may be present in some waters, yet absent in others near by. This is usually due to a difference in the water. Xylotrya appears to be able to endure the brackish water of the inner New York Harbor, while Teredo can not live there, though it is present in the ocean just outside. The shipworm is very active on the north Pacific coast, yet it is absent about the mouth of the Columbia River, where the amount of salt in the ocean is influenced by the inflow of fresh water. The effect of water conditions was also noticed in Holland during certain years in which the worms were unusually destructive. Little rain fell during those years, and the small amount of river water brought to the coast was thought to have allowed the ocean to become more saline about the mouths of these streams.

Analyses show that there is a variation in the proportion of salt present in the waters of the coast during the dry and the rainy seasons.

Observations along Chesapeake Bay and the Gulf of Mexico indicate that the species found there will thrive in waters with a saline density indicated by a specific gravity of from 1.0054 to absolute saturation, 1.0333; that they thrive in temperatures of from 55° F. to the highest found along our coasts; that they work in absolutely clear and in very turbid water; that they seldom work to a depth of over 30 feet, and that the worst attack is usually in the very salty, warm, clear waters.

The length of time required to destroy an average, barked, unprotected pine pile in different localities is shown in the following table:

| Locality. | Length of life reported. | |
|---|---|---|
| | Average. | Minimum. |
| Colon, Panama | 9 months–1 year | |
| Norfolk, Va | 5 years | 1 year. |
| Newport News, Va | 2 years | |
| Hampton Roads | 1½ years | |
| St. Andrews, Fla | 2–3 years | |
| Pensacola, Fla | 2–3 years | 1 year. |
| Fort Morgan, Ala | | 1 year. |
| West Pascagoula, Miss | 2–3 years | 1 year. |
| Texas City, Tex | 1 year | 29 days. |
| Galveston, Tex | 1½ years | 5 months. |
| Aransas Pass, Tex | 1 year | 3 months. |
| Puget Sound | 1 year | |
| Klawak, Alaska | 3 years | 18–20 months. |

From this table it will be seen that the average life of an untreated pine pile on the Atlantic coast south from Chesapeake Bay and along the entire Pacific coast is but from one to three years.

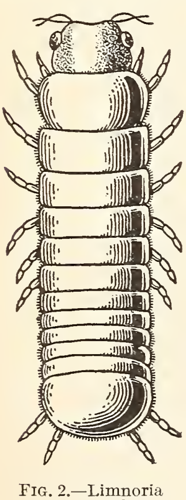

Fig. 2.—Limnoria (enlarged).

## LIMNORIA.

Of the crustacean borers, Limnoria, or the "wood louse," is the only one of great importance. It is gregarious in its habits, and is about the size of a grain of rice. (Fig. 2.) The wood in which it tunnels furnishes both food and shelter. Boring is done with very sharp mandibles. The little galleries excavated are about one-half inch long and only slightly larger in diameter than the borer. (Fig. 3.) The galleries extend inward radially, side by side, in countless numbers, so that the wood partitions between them are very thin and are soon destroyed by wave action, thus exposing a fresh wood surface to attack. Boring is carried on at the rate of about one-half inch per year. Soft and hard woods are both destroyed, but soft woods much more quickly. If possible

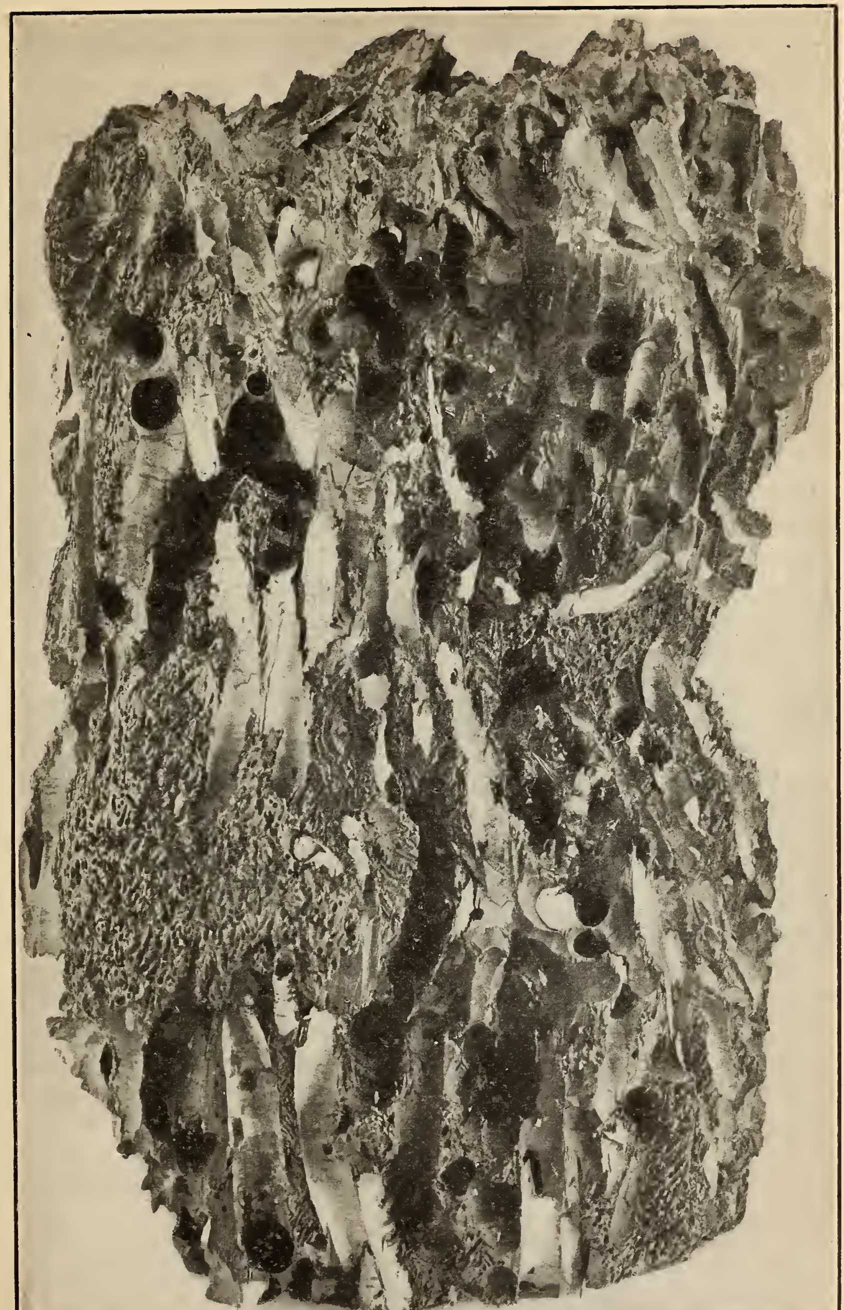

FIG. 3.—Portion of pile destroyed by Xylotrya and Limnoria.

knots, dense summer wood, and other obstructions are avoided. The attack is usually centered upon a limited zone above and below low-water mark. Hence where the tide is great the surface exposed to attack is large.

Limnoria is reported by the U. S. Fish Commission as occurring rarely at a depth of 40 feet. It has a wider temperature range than Xylotrya, but requires pure salt water and can not exist in dirty or fresh water. It is found along the Atlantic coast from Florida to Nova Scotia. It occurs sparingly in Long Island Sound, is quite abundant along the coast of Massachusetts and in the Bay of Fundy. It also does great damage along the whole Gulf of Mexico, on the north Pacific coast around Puget Sound, and in the Straits of San Juan de Fuca.

## WOODS ATTACKED BY BORERS.

All the woods commonly used for piling are subject to the attacks of marine borers. Some doubt has been expressed whether borers attack certain species which are not indigenous to this country and some native woods that have an extremely porous structure. Examples of the first class are certain eucalypts, and of the second class, palms and palmettos. From investigation it is clear that species of the first class are not immune from attack, and that those of the second, although practically immune, are found in such small quantities and are so lacking in the requirements of structural timbers that the fact is not important. Hardness is no barrier to attack, although boring is probably slow in dense woods like ebony, eucalyptus, etc. Whenever partial or complete immunity is reported, it is perhaps largely due to local conditions rather than to the kind of wood.

## PROTECTION FOR MOVABLE STRUCTURES.

1. *Removal during the breeding season.*—The attack of shipworms can sometimes be prevented by removing the exposed structures from the water during the breeding season. This, however, necessitates the temporary substitution of other structures. Furthermore, it is not effective in the South, where the breeding season continues throughout the year, and nowhere is it effective against Limnoria, which breeds in the North, as well as in the South, during all seasons.

2. *Change of water.*—Borers which have gained entrance into wooden vessels can be killed by running the infected vessels into fresh water.

## PROTECTION FOR PILING.

Piles may be protected by the following methods:

1. *External coatings.*—These need be applied only to the portions of the pile exposed to attack, while the parts below the mud line and

above high water, often 50 to 60 per cent of the entire pile, can be ignored.

(*a*) Bark left on the pile. This is an absolute protection against marine borers as long as it remains intact. (Fig. 4, *a*.) On the other hand, above the water line it offers an excellent place for insects and fungi, both of which may assist materially in the destruction of the pile.

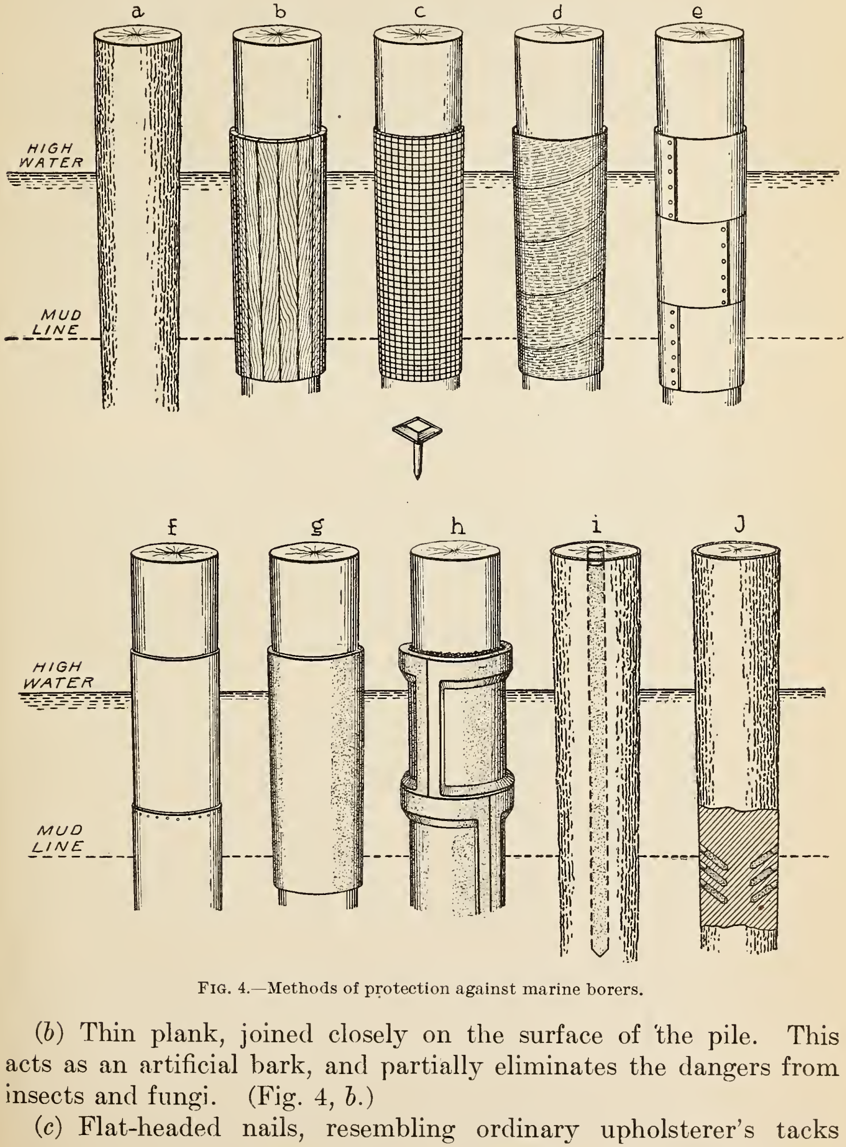


FIG. 4.—Methods of protection against marine borers.

(*b*) Thin plank, joined closely on the surface of the pile. This acts as an artificial bark, and partially eliminates the dangers from insects and fungi. (Fig. 4, *b*.)

(*c*) Flat-headed nails, resembling ordinary upholsterer's tacks except that the heads are square, and larger. These are driven in

close together, forming a continuous covering over the exposed surface. (Fig. 4, *c.*)

(*d*) Hot paints, tars, asphalt, etc. These are applied alone, or are further reinforced with fabrics, such as burlap soaked in the mixture or strips of coated batting. (Fig. 4, *d.*) Some of the combinations which have been used are:

A mixture of asphalt, coal tar, oxide of copper, fish oil, oxalic acid, and salt, in varying proportions, applied hot to the barked pile, and protected with strips of batting to prevent breaking the coating during handling.

A mixture of coal tar, pitch, and asphaltum, in varying proportions, applied hot to the barked pile; then a mixture of ground glass and flint sand added. This is protected by narrow strips of batting, coated with a mixture of all of these substances.

A mixture of slaked line, asphaltum, hydraulic cement, brimstone, crude creosote, and asbestos in varying proportions, applied hot to the barked pile; then sharp sand or crushed granite added, and the whole wound with a fabric such as coarse burlap soaked in the above mixture.

A mixture of tar asphalt, paraffin, cement, phosphorus, and hair applied hot to the barked pile; then a mixture of fire clay, sand, and cement added as a further protection.

(*e*) Metallic sheathings. Thin sheets of copper, yellow metal, or zinc are fastened over the entire exposed surface of the pile with copper nails, or sections of iron pipe are bolted together around it, and packed with cement or sand. These form a solid mechanical barrier against the entrance of borers. (Fig. 4, *e* and *f.*)

(*f*) Cement casings. These are made in two ways, (1) with no space between the casing and the pile, and (2) with an intervening space of from 2 to 4 inches.

The first are manufactured as follows: The bark and knots are removed and the pile driven. A jacket of iron, wood, or sewer pipe is placed around it, and the space between jacket and pile, which is from 2 to 4 inches wide, is filled with hydraulic cement. When this becomes hard, the jacket is removed. Some jackets are so made that they can be applied to the pile without disturbing the superstructure of the wharf, thus making repairs to broken casings easy. (Fig. 4, *g.*)

The second class is composed of cement pipes divided longitudinally into two halves, which, when placed together around the pile, are joined by a scarf joint keyed with a wooden plug soaked in hot tar. These are made in iron molds nearby and are placed around the pile from a raft. The intervening space between pile and casing is filled with sand. (Fig. 4, *h.*) The chief advantage of this kind of casing

is the fact that broken sections can easily be replaced without removing the superstructure of the wharf, an operation which would otherwise make replacement very expensive.

(*g*) Earthenware pipes, joined by a special cement. These are lowered over the piles when driven, and the intervening space is filled with sand. The top section is either left open or capped with cement.

2. *Preservative treatments.*—(*a*) Injection through holes bored in the pile. A single hole is bored longitudinally into the top end of the pile to a point which will be below the mud line when the pile is placed. This hole is filled with a poisonous substance, such as corrosive sublimate, and plugged. (Fig. 4, *i*.) Though hydraulic or steam pressure is sometimes used to distribute the poison through the wood, natural diffusion is generally relied upon. Holes are sometimes also bored diagonally near the ground line. (Fig. 4, *j*.) Capillarity is supposed to carry the poison upward throughout the pile. External coatings of other material are sometimes used in addition.

(*b*) Injection of oils or soluble salts. This is done by means of pressure applied in a closed cylinder under proper temperature conditions. By this method the entire pile is treated instead of the exposed portion alone, as in the case of the preceding method.

## EFFICIENCY OF METHODS.

Experience has shown that marine borers require only a minute exposed surface in order to gain entrance and completely destroy a pile. Therefore, to be effective, all external coatings must maintain an absolutely intact covering over the wood, while preservatives applied through holes bored into the pile should penetrate every portion of the surface layer. Since all protective measures are expensive, the natural life of the pile must be increased sufficiently to offset the cost of treatment.

Any of the external coatings or sheathings properly applied will increase the life of the pile. There are three factors, however, which decrease their efficiency. These are (1) the chemical action of salt water, which corrodes metallic sheathings; (2) the mechanical action of waves which wash the fillers from the casings, and often break the casings themselves, and (3) the danger from floating timbers and débris, which strike the coatings and break them. The last factor is the most serious. One blow from a floating timber will often ruin the protective covering of a pile. Thick iron casings resist the chemical and mechanical factors for a long period, but their initial cost is so great that their use must be limited.

It is thus apparent that the efficiency of external coverings depends largely upon local conditions. Repeated trials have shown that such coverings do not pay in situations where structures may be exposed

to heavy waves, and where there is much débris afloat. When properly carried out the injection of chemical preservatives has been found to be much more efficient. The injection of preservatives through holes bored in the top of the pile, or near the mud line, has proven inadequate, however, owing to the insufficient and irregular distribution of the preservative. All soluble salts, no matter how applied, have shown a tendency to leach out when exposed to salt water.

The injection of creosote, or dead oil of coal tar, through the outer portions of the pile has failed in some cases and has proved highly efficient in others. The oil should be insoluble in water and should penetrate the pile to a depth sufficient to prevent blows from floating débris exposing the untreated wood in the interior. When properly handled this treatment forms a solid, antiseptic magma that borers will not penetrate. Where failure has occurred it can be attributed (1) to the use of inferior or adulterated oils, (2) to the use of an insufficient quantity of oil, (3) to imperfect preparation of the timber before treatment, (4) to unsuitable kinds of timber, and (5) to a combination of these causes.

Oil is often used which contains a large proportion of easily volatile or soluble constituents. These soon disappear from the pile, and the preservative value of the treatment is lost. Creosote may also be adulterated with other cheaper soluble or nonantiseptic oils. Specifications should be adopted which will insure the prevention of such adulteration.

If not enough oil is used the zone of wood penetrated will be too thin to prevent mechanical abrasion or the impregnation will be too dilute to prevent the attack of borers.

Treatment of green or water-soaked timber may result in an insufficient or uneven penetration.

Attempts are sometimes made to drive oil into wood too dense to impregnate by ordinary means. In order to do this temperatures are employed which destroy the outer fibers of the wood, thus reducing its ultimate strength.

The chief objection to the use of creosoted piling is the high cost of treatment. This depends upon the quality and quantity of oil used and the method of treatment. With certain kinds of timber a great saving should be possible over the methods now in use.

At present the preservative treatment of piling usually consists of several operations. These, it is claimed, are made necessary by the character and condition of the timber used. In most cases the wood is first steamed from six to eighteen hours at a relatively high temperature. This is supposed to dissolve the soluble cell contents and expand the moisture and air in the cells and intercellular spaces.

Next it is subjected to a high vacuum, in order to draw out the air, moisture, and solids. Oil is then allowed to flow into the cylinder, and is forced into the wood under heavy pressure until the required amount has been injected.

Whether long steaming is of any great advantage, even in the treatment of woods of dense structure, and whether the vacuum really draws out the supposed moisture and solids is a much-debated question. It has been shown by experiment that unless the wood is very green or water-soaked at the time of treatment it is increased in weight after the steam and vacuum process. Hence it would seem that by such treatment moisture is absorbed instead of lost.

The Forest Service has made a special study to devise a cheap and efficient method for the preservative treatment of timber. As a result of many experiments the "open tank" method has been evolved. In the case of piling and other large timbers which are to be impregnated throughout their length this consists in subjecting them to alternate baths of hot and cold creosote in a horizontal closed cylinder. (See fig. 5.) The piling should be air-seasoned for varying periods, depending upon the species of timber and the climate. It is then placed upon iron cars and is run into the cylinder. The door is closed, and the cylinder is filled with creosote from a large storage tank. By means of steam coils arranged along the bottom of the cylinder the creosote is heated to a temperature of from 200° to 230° F. and is held at that point for a period depending upon the species and condition of the timber. If the timber is thoroughly air-seasoned, from three to four hours is sufficient, but if it has a higher moisture content a longer period may be necessary. At the conclusion of the hot bath the creosote is allowed to run from the cylinder into an underground receiving tank. At the same time a fresh supply of cold oil is admitted into the cylinder from the storage tank. The timber is allowed to remain in this for a short period, and after the oil is allowed to run into the receiving tank, from which the hot oil has meanwhile been pumped back into the large storage tank, the cylinder is opened and the cars of treated piling withdrawn by means of a cable operated by an engine placed a short distance from the cylinder. The cylinder is then available for another charge.

During the hot bath the temperature of the outer layers of wood is raised sufficiently to expand the air in the wood cells and intercellular spaces. This escapes through the creosote. It is probable that in imperfectly seasoned timber some moisture is expanded and driven out, but wood is such a poor conductor of heat that appreciable evaporation of moisture takes place only in the extreme outer layers when the wood is subjected to safe temperatures. For every degree of heat below its boiling point the expansion of water is much less than

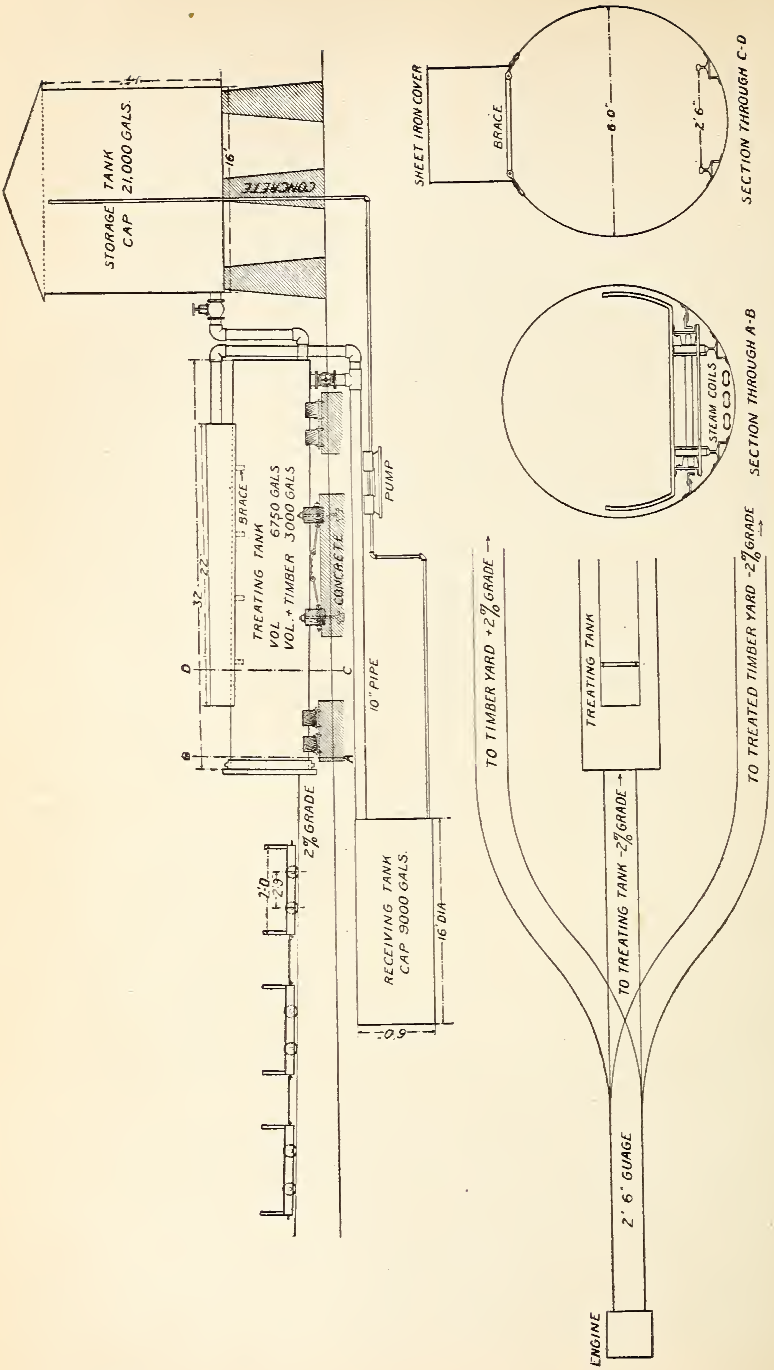


Fig. 5.—Open tank treating plant adapted for piling.

that of air, consequently a slight increase in temperature in the interior of the stick causes the air to be expanded and expelled to a far greater extent than the moisture.

During the cold bath the temperature of the timber is lowered, with a consequent contraction of the air and moisture it contains. A partial vacuum is thus formed which permits the preservative to be forced into the timber under atmospheric pressure. In this way are secured results similar to those obtained by the artificial pressure of other processes.

By a proper application of this method all pile timbers having wide sapwood, such as loblolly and shortleaf pines and the gums, can successfully be preserved against the attacks of marine borers. A very thorough and even penetration of the creosote can be secured without danger of exposing the timber to excessive temperatures which might affect its strength. The necessary apparatus can be installed at a cost less than one-fourth of that of a pressure-cylinder plant of the same daily capacity. In the treatment of the denser timbers, such as Douglas fir and longleaf pine, in which there is a comparatively small amount of sapwood, it is a question whether the atmospheric pressure developed in the open tank is sufficient to secure a deep and uniform penetration of creosote. But with the class of timber mentioned above there is no doubt.

## CONCLUSION.

The use of properly creosoted material for piling should be extended. The denser timbers should never be treated for piling, because of the difficulty of securing a satisfactory penetration of the oil. On the other hand, timbers of open grain, like loblolly pine, are easily penetrated, and embody all of the characteristics of an ideal pile timber. Their use should therefore be encouraged. A uniform and satisfactory penetration can be secured with such timbers if properly air-seasoned before treatment. Since this can be accomplished with an entire elimination of the expensive "pressure-cylinder" process, 50 per cent or more is saved in the time required for treatment, and thus, even with the expense of holding the material for air seasoning, the ultimate cost is much reduced.

Approved:

James Wilson,

*Secretary of Agriculture.*

Washington, D. C., *October 2, 1907.*



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